

CONTROL OF CARBON COATING MICROCRACKINGS IN  
FABRICATION OF FUEL CELL GDL ELECTRODE LAYER(S)

Field of the Invention

5           The present invention relates to a coating to be applied to the surface(s) of a gas diffusion layer or electrode of a fuel cell or battery having carbon or graphite particulates.

Background of the Invention

10           Gas diffusion layers ("GDLs") of fuel cells or batteries, which may be carbon fibers in a non-woven or woven form, are generally coated on one or more sides with a substance to form an electrical contact between the GDL and either a membrane or bipolar plate within the fuel cell. Such coatings may be fabricated from a mixture of carbon black (also known as Acetylene Black or  
15   amorphous black) and a fluoropolymer such as Teflon®.

          In order to achieve high fuel efficiency for the fuel cells or batteries, control over the size and porosity of the coating should be exercised. The porosity affects several functions including forming further pathways to control the flow of fuel to a catalyst and membrane, regulating the amount of water near  
20   the membrane, and supporting the catalysts themselves.

          The coatings are formed using aqueous solutions having low solid loadings. When a large amount of fluid is removed, cracks or mud cracks frequently occur in the coating on the surface of the GDL. The cracks may become more pronounced when heavier coatings are deposited on the surface of  
25   the GDL. The more severe the cracking, the lower the effectiveness of the GDL to accomplish some of its functions such as good electrical contact and control of fuel and water transport. An example of such cracks in the coating of the surface of the GDL is shown in Figure 1.

Cracking in the GDL coating can be prevented by using larger amounts of carbon black. However, such larger amounts of carbon black cause the viscosity of the solution to increase, which adversely affects the quality of the coating. Accordingly, in order to obtain a good quality coating, the viscosity of the solution needs to be kept low.

#### Summary of the Invention

In accordance with the present invention, a coating for a gas diffusion layer or electrode of a fuel cell or battery is provided which inhibits cracking.

10 The coating comprises a mixture of carbon black, a fluoropolymer, and one of graphite and carbon particulates. The majority of the particulates are substantially larger in size than the particles of the carbon black which may be within the range of approximately 13-95 nm. Small amounts of smaller size elongated particulates may however be added to also control other properties of the coating, for example enhance electrical conductivity or support catalyst.

The carbon particulates may be cut or chopped carbon fibers, carbon or graphite flakes or platelets, carbon nanotubes, carbon fibrils, or carbon whiskers.

The carbon particulates may have a high length to diameter ratio.

Other features and advantages according to the present invention will become apparent from the following detailed description of the illustrated embodiments when read in conjunction with the accompanying drawings in which corresponding components are identified by the same reference numerals.

#### Brief Description of the Drawings

25 Fig. 1 is a view of a coating on a gas diffusion layer fabric having micro cracks;

Fig. 2 is a view of a coating on a gas diffusion layer fabric according to an embodiment of the present invention; and

Fig. 3 is a diagram of a fuel cell having a number of electrodes to which the present coating may be applied.

#### Detailed Description of the Preferred Embodiment

5           In the present invention, an aqueous solution is used to form a coating on GDL fabric of a battery or fuel cell (such as a methanol type fuel cell). The solution may include carbon black, fluoropolymers, and either carbon or graphite particulates. The ratio of fluoropolymer to carbon black may fall within the range of 5/95 to 70/30 by weight. The particulates may comprise 25  
10   to 70% of the total coating weight. The addition of these particulates allows for a greater structural integrity as well as increasing the solution solid loading without increasing the viscosity. As a result, the present coating inhibits cracking in the coating on the surface of the GDL.

          Carbon black is a black, amorphous, carbon pigment produced by the  
15   thermal decomposition of natural hydrocarbons. Generally, there are three different types of carbon black (i.e., furnace, channel, and lamp black). It has a nominal purity that is roughly equivalent to 98.5% to 99.6%. The size of carbon black particles can be anywhere from 13 nm to 95 nm. Carbon black may have a spherical shape.

20           The size of the majority of the particulates may be substantially larger than the size of the carbon black particles. The particulates may have a length that is greater than the diameter thereof. A ratio of the length to diameter may fall between 1.5 to 10000. The particulates may include short length fibers such as cut carbon or graphite fibers, carbon or graphite flakes or platelets, carbon or  
25   graphite nanotubes, carbon or graphite fibrils, or carbon or graphite whiskers. The fibers may be 6 to 20 microns in diameter and 10 to 500 microns in length. The flakes or platelets may be 1 to 500 microns in length. The nanotubes, fibrils, and whiskers may be 5 to 100 nm in diameter and 5 to a few hundred microns in length. The introduction of these fibers into the coating may provide

for a transition layer that brings the characteristic of the coating closer to one of the fibrous diffusion media. In addition, due to the geometry of these particulates, a bridge between cracks may be provided to prevent further widening of any cracks during the drying process.

5           Figure 2 depicts a coating on the surface of the GDL that includes chopped carbon fiber. As can be seen in the figure, there does not appear to be any visible cracks in the coating.

          In addition to the above-described particulates, graphite flakes or platelets may also be added to the coating to control the flow of fuel or water  
10       within the layers of the fuel cell or battery. While the coating is formed, the flakes or platelets may orient themselves to be in parallel with the plane of the coating. Such orientation of the flakes or platelets may provide an obstacle in the fluid path so as to control the direction of the flow.

          In addition to preventing the formation of cracks in the coating, the  
15       introduction of the particulates may also enhance electrical conductivity in the coating.

          The coating may be applied to GDL fabrics or any other GDL media within a fuel cell or battery. The GDL (fabric) media may be formed from fibrous carbon preforms that can be of short length, paper, unidirectional tape,  
20       woven and non-woven fabric including knitted, stitch bonded multi-axial fabric, 2 and 3 directional fiber weaves. Lower cost fibers, such as fiberglass or other fillers (carbonaceous conductive and non-conductive fillers) may be combined with the carbon fibers in a needled mat to reduce cost. Coating may be applied using a variety of techniques such as dip coating, doctor blade, etc.

25       A fuel cell may include a housing that may be impervious to the passage of gas therethrough. In the housing, there may be two internal cell separators that define a series of three cells. Each cell may include a pair of electrodes made from a carbonaceous material. The electrodes may be introduced into adjacent cells having a different polarity. The electrodes may be single bent

pieces, which are adapted to be insertable into adjacent cells. Alternatively, an electrode can be made of two pieces and connected in a manner such that the two connected pieces act as a single electrode. In between the electrodes a foraminous membrane may be provided such that ions may be allowed to pass  
5 through the membrane.

Figure 3 shows an example of fuel cell 100. Fuel cell 100 may include, among other things, an end plate 101, current collector 102, bipolar plate 103, gas passage 104, GDL 105, catalyst layer 106 and a proton exchange membrane 107 arranged as shown in Figure 3.

10 Therefore, in the present invention, a GDL fabric of a fuel cell or battery may be coated with an aqueous or solvent based suspension (placed in the aqueous solution environment), which includes carbon black, fluoropolymer, and the particulates. A large amount of the fluid therefrom is removed and the coating is allowed to dry. As a result, a coating with a minimum amount of  
15 cracks can be manufactured.

Accordingly, the introduction of the particulates may significantly reduce the amount of cracking in heavy coatings prepared for GDL fabrics. Total coating amounts of up to  $300\text{g/m}^2$  may be manufactured with a minimum number of cracks as a result of these particulates. Since methanol fuel cells  
20 require heavier coatings than their hydrogen fueled counterpart, the above-described mixture is particularly advantageous in those instances.

Although a preferred embodiment of the present invention and modifications thereof have been described in detail herein, it is to be understood that this invention is not limited to this precise embodiment and modifications,  
25 and that other modifications and variations may be effected by one skilled in the art without departing from the spirit and scope of the invention as defined by the appended claims.